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Wind Energy in the United States: Market and Research Update

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WIND ENERGY IN THE UNITED STATES: MARKET AND RESEARCH UPDATE

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ABSTRACT: U.S. market activity has increased over the last two years. In 1998, new capacity totaled about 150 MW and projected 1999 capacity additions are over 600 MW. As the electricity market continues to evolve under restructuring, the U.S. Department of Energy (U.S. DOE) Wind Energy Program has positioned itself to work with industry to meet current challenges and opportunities, and prepare for the market of tomorrow. Some opportunities include green power markets and distributed applications, although a primary challenge involves the fact that avoided cost payments to renewable generators are not high enough to economically support projects. A recently incorporated power exchange in California, APX, Inc., has demonstrated that green power does attract a premium over prices on the conventional power exchange. The key elements of the U.S. DOE Wind Program are (1) Applied Research, which is critical for achieving advanced turbine designs capable of competing in a restructured market that emphasizes low cost generation; (2) Turbine Research, which supports the U.S. industry in developing competitive, high performance, reliable wind turbine technology for global energy markets; and (3) Cooperative Research and Testing, under which standards development and certification testing are the key activities for the current year.

KEYWORDS: Markets, Programmes, R&D, Test Windfarms/Stations

1. INTRODUCTION

After a number of years of low level activity in the U.S. wind energy market, optimism is increasing, and substantial new wind capacity is being installed. As electric utility restructuring progresses, both new opportunities and challenges for wind generation will continue to emerge. Although much of the market is still evolving and many questions remain unanswered about its future, it is clear that the cost of energy from wind technology will require continued reduction for wind to compete effectively.

As market conditions have evolved, so has the U.S. Department of Energy (U.S. DOE) Wind Energy Program (henceforth referred to as "the Program"). The Program structures its activities towards establishing wind technology that can compete in the new environment. The current levelized cost of energy is well under US$0.05 per kWh (assuming constant dollars, a 30 year project life, and 6.7 m/sec average annual wind speed measured at 10 meters above the ground). Using this same set of assumptions, the Program goal is to achieve US$0.025 per kWh by the year 2002. This paper describes the status of recent U.S. electricity market developments and commercial wind energy projects. It then discusses some of the major RD&D activities being sponsored by U.S. DOE during the current year.

1.1 U.S. Market Status

Utility market restructuring continues to proceed in many, but not all, states. This pattern of uneven progress is likely to continue into the foreseeable future. As of June 1998, 12 states had passed legislation establishing retail competition, and the public utility commissions in six other states have issued regulatory orders introducing retail competition. In parallel, the federal government is working on national restructuring legislation. Although federal legislation is not a requirement for promoting retail competition, it would be useful in advancing the economic and social benefits of competitive markets and in reducing jurisdictional conflicts.

The first state to restructure its market, California, formed an independent system operator (ISO) to manage the transmission system and a power exchange to handle real-time power marketing. A second, private power exchange (Automated Power Exchange, Inc. [APX], established in March 1998) matches renewable energy producers with retail providers who want to provide "green" or renewable power to their customers. It has over 50 signed participants, including large power marketers, out-of-state utilities, unregulated subsidiaries of investor-owned utilities, municipal utilities, and electric service providers.

Typically, green energy commands a price premium, and such prices are published monthly by APX. Average hourly APX green prices, during the last 6 months of 1998, ranged from US$32.54/MWh to US$45.09/MWh for on-peak purchases, and from US$27.22/MWh to US$31.75/MWh for off-peak purchases. These represented premiums of about US$0.003/kWh to US$0.01/kWh over prices on the California Power Exchanges (PX). The overall range for all hourly purchases on the green power market was from US$14.65/MWh to US$145/MWh.

Most green power being sold on the APX is from existing sources of generation. Although this may be a necessity in the early stages of the market, there are signs that as retail customer demand is demonstrated in the marketplace, new capacity will be built to meet those consumer preferences. For instance, Green Mountain Energy Resources, a green power provider and marketer participating in the California APX market, announced the ground breaking for two new 700 kW wind turbines in California as a direct outcome of customers selecting its *Wind for the Future*SM product in California's retail market. Despite this progress, the potential for additional capacity from similar projects is still not well understood.

In addition to green power, another potential opportunity for wind power in the restructured market is distributed applications. The Wind Program, along with the National Wind Coordinating Committee, (a multi-stakeholder collaborative formed to support the responsible use and prudent acceleration of wind power in the United States), is currently assessing this issue. If economic and regulatory systems can be established to recognize and credit owners of distributed wind generation with the benefits that accrue to the distribution and transmission system under certain circumstances, then

the owner would be able to recover more than just the avoided cost of generation.

Nationally, avoided costs rates (the rates utilities are required to pay for small, independently produced power from facilities qualifying under federal legislation that guarantees access for such generators) are typically in the range of US$0.015-0.025/kWh. Even with the current US$0.017/kWh federal production tax credit, not many wind power projects are economical at such low avoided cost rates. Many of the recently installed large wind power projects have used the tax credit in conjunction with a bidding process that has resulted in a purchase price higher than the utility avoided cost. Legislation mandating new capacity – especially in Minnesota and Iowa – and the imminent expiration of the tax credits this summer have been primary drivers of recent installations (see Figure 1). A recent decision by the Minnesota Public Utilities Commission to require an additional 400 MW by 2012 will continue that trend. Substantial repowering of older projects in California has begun and will continue during the next several years. Typically, many older turbines are replaced by a single, larger, more efficient turbine, which improves the visual aspect of the windfarm and increases energy output for the same amount of nameplate capacity. The pace of non-mandated capacity additions after this summer is clouded by the uncertain status of pending legislation for extending the tax credits.

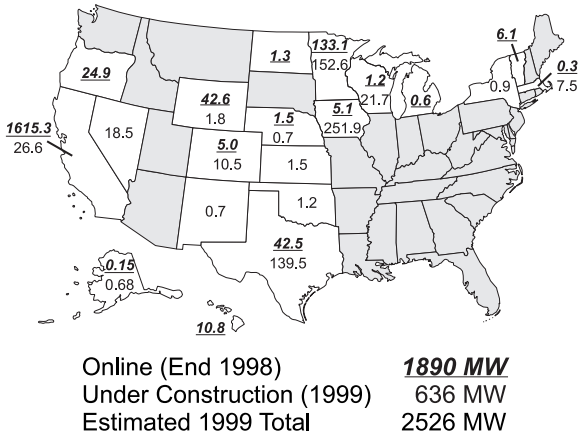


Figure 1: U.S. wind energy capacity.

2. U.S. DOE WIND ENERGY PROGRAM

2.1 Program Mission and Strategy

The mission of the U.S. DOE Wind Energy Program is to enable U.S. industry to complete the research, testing, and field verification needed to fully develop advanced wind technologies that lead the world in cost effectiveness and reliability. The Program accomplishes this mission through two of U.S. DOE's principal laboratories, the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL). The Program works closely with industry, utilities, environmentalists, and other stakeholder groups through the American Wind Energy Association, the National Wind Coordinating Committee, and the Utility Wind Interest Group.

The National Wind Technology Center (NWTC) is located near NREL in Colorado. Expertise is provided to the NWTC from both NREL and SNL. Between the two laboratories, capabilities exist to thoroughly explore all of the issues faced during the development of advanced wind technology. The NWTC is a world-class research facility that supports research, development, and the testing needs of industry. It houses laboratories, offices, and field test facilities for the three major research programs in the Wind Energy Program: (1) Applied Research, (2) Turbine Research, and (3) Cooperative Research and Testing (see Figure 2).

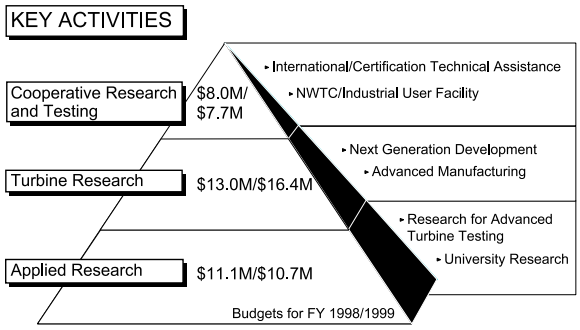


Figure 2: U.S. DOE Wind Energy Program.

2.2 Applied Research Program

The Applied Research program addresses fundamental engineering and technology issues with a broad range of applications. The burden of achieving advanced turbine designs capable of competing in a restructured market emphasizing low-cost generation must fall on applied research. Ultimately, a much better understanding of the design and safety factor tolerances driving cost and reliability must be achieved if advanced turbine system designs are to be truly optimized.

Understanding the fundamental behavior of unsteady horizontal-axis wind turbine (HAWT) aerodynamics is critical to reducing design margins while keeping structural loads and resulting fatigue within tolerable limits. This is especially important if turbine designs are to become lighter and more flexible. The goal of the aerodynamics program is to couple aerodynamics loads and performance codes with field test and wind tunnel data to improve current design codes. Current applied research activities to address this goal involve measuring aerodynamic and structural parameters of a highly-instrumented experimental 10-m diameter wind turbine in two-bladed, teetered and rigid configurations. In conjunction with that field data, full-scale wind tunnel testing scheduled for November 1999 will provide data that will benchmark future aerodynamic code development.

Recent tests on the Cannon Wind Eagle turbine were conducted to validate current structural codes for flexible systems. One hypothesis to emerge from the testing is that small differences in blade mass and stiffness may create large differences in angles of attack, resulting in unwanted cyclic variation in torque and power. Further work will include comparison of code predictions with measured data and validation of analytic models under turbulent wind inflow conditions. Also, further analysis will be conducted to better understand the source of some of the largest loads identified during the initial tests.

An integral part of the development of the NWTC has been the establishment of an Advanced Research Turbine (ART) test bed. This facility utilizes large commercial turbines, redesigned for conditions at the NWTC, to support testing of large-scale components compatible with current turbine design activities for large turbines. The first turbine (of three) serves as a baseline for future tests and additional turbines. The second, which will be operational by Fall 1999, incorporates a variable-speed generation system to allow

variable-speed testing on a full-scale turbine. It also has a combined supervisory data acquisition and control system (SCADA) based on the experience gained from the ongoing "combined," or unsteady aerodynamic experiment at the NWTC. In the near-term, follow-on work on the ART will include development of a lightweight, very flexible rotor.

The ART will also be used for the Long-Term Inflow and Structural Testing (LIST) program. LIST is a joint, basic science program between NREL and SNL to understand inflow and resulting loads in the turbine system, and what atmospheric events – especially rare ones – the turbine will experience over its lifetime that can heavily influence fatigue lifetime.

Bringing down the cost of energy requires either improving energy capture, reducing capital costs, or reducing maintenance. The Materials, Manufacturing, and Fatigue task attempts to positively affect the last two elements. The cost of wind turbine blades can be reduced while simultaneously improving reliability by improving material properties obtained through the manufacturing process. The fatigue properties of existing materials have been catalogued through the Montana State University database. The factors that affect fatigue durability in typical blade composite materials have been identified. The task of realizing improvements based on these findings lies in the manufacturing research program. Under this program, improvements in manufacturing processes not yet implemented by the wind community are researched, components are built and tested, and innovative manufacturing processes are brought to bear on whole blade design. A tool for blade design analysis called NuMAD has been created to help blade designers evaluate the details that affect blade strength and reliability. Improved inspection techniques, either in the field or on the manufacturing floor are also being investigated to reduce maintenance expenditures.

Cost cannot be brought down below the level of material needed to meet design specifications. The specifications themselves can therefore be a limiting factor in the cost of energy. Work is also conducted in estimating the standards that specify safety factors on loads and strength used by designers. Statistical extrapolation and probabilistic analysis tools have been developed to evaluate how these uncertainties affect reliability. These tools are being used to evaluate the safety factors currently in practice and to guide the development of more consistent design margins. And because loads are only partially known from short-term prototype testing and numerical analysis, there is an extensive program in Long-Term Inflow and Testing aimed at determining what in-flow models must contain to adequately simulate response in the computer models and to measure how the long-term load response of turbines relates to short term testing results.

The Wind Energy Program supports a range of activities directed at advancing the development and deployment of wind hybrid systems. The Hybrid Power Test Bed (HPTB), at the NWTC, supports industry development and validation of innovative wind hybrid systems, components, and concepts. The HPTB has the capability to simulate loads and connect/disconnect loads, storage, and other generators from a central control. When combined with subsequent field testing and demonstration, research conducted on the HPTB provides industry with the opportunity to move hybrid technology from the conceptual stage to commercialization.

For example, a current project involves development and lab-testing of a high penetration wind-diesel control system at the HPTB, and then relocating the system for a pilot project in Wales, Alaska, a small village on the Bering Straits. NiCad batteries will be used for energy storage. In addition, waste heat from the diesel generator will be utilized, creating a totally integrated energy system. The Wales project will be built and operated by the Kotzebue Electric Association (KEA, a rural Alaskan electric utility) in collaboration with the Alaska Department of Community and Regional Affairs - Division of Energy (DCRA/DOE) and the Alaska Village Electric Cooperative (AVEC), the local utility in Wales. KEA will then sell the power to AVEC. KEA was able to draw upon their experience with a current U.S. DOE-sponsored field validation project of their own. Assuming a 33% capacity factor, a diesel displacement of 13 kWh/gal, and a diesel cost of US$0.90/kWh, KEA's annual fuel cost savings from its 10 turbines is about US$100,000 per year. KEA's favorable experience has led them to view wind power as a business opportunity, based on the Wales project as a model.

2.3 Turbine Research Program

The Wind Energy Program sponsors a multifaceted Turbine Research program to assist U.S. industry in developing competitive, high performance, reliable wind turbine technology for global energy markets. The Program is performing research on systems and components for the near-term, including cold weather technology, for next generation large turbine system development, and for small wind turbine system development for use in a wide range of commercial applications. Figure 3 summarizes the turbines included in this program. Another paper presented at this conference discusses these turbines in detail (Calvert and Migliore, "U.S. Department of Energy Wind Turbine Development Projects").

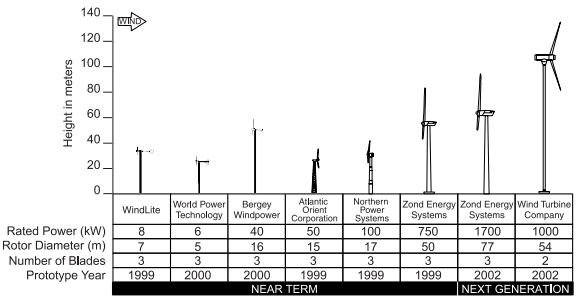
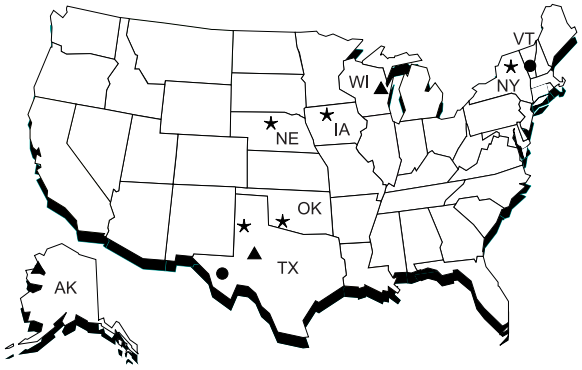


Figure 3: Current turbine development projects.

NREL has operated a structural test facility since 1990. The NWTC's new Industrial User Facility (IUF), now in full operation, incorporates this and other capabilities with the goal of encouraging government industry collaboration in technology innovation. In addition to blade testing, other major activities conducted at the IUF have included development of components for the new ART test bed, support for turbine deployment and industry and laboratory testing at the NWTC, lab facilities to maintain certification testing equipment, and outfitting of data vans that can be deployed for certification testing and modal testing in the field. To date, NREL has performed fatigue and static testing on over 70 blades. In addition, Program researchers have conducted experiments and testing with several non-destructive fatigue evaluation techniques at the IUF. Data from laboratory structural tests will be used to validate engineering design assumptions and models, and to qualify components for field operation and international certification. Certification of wind turbines will likely involve wind turbine blade structural testing in the near future. The development of standard testing procedures and international accreditation for NREL's facilities will be key areas of near-term focus.

The 2.5-MW Dynamometer and Spin Test Facility is a new test bed being developed at the NWTC. This facility, scheduled to be completed in Spring 1999, will provide unique testing capability to the U.S. industry and Turbine Research projects for wind turbine drive trains, drive train components, and power systems. It will be used to conduct such tests as gearbox fatigue, wind turbine control simulations, transient operation, and generator and power system component efficiency and performance.

In 1992 the Electric Power Research Institute (EPRI) and U.S. DOE initiated the Utility Wind Turbine Verification Program (TVP) to evaluate early commercial wind turbines at several sites developed by U.S. electric utilities. Two initial projects of 6.6 MW and 6.0 MW have been in operation for several years. The most recent round has resulted in three projects plus three additional associate projects. These focus on distributed projects ranging in size from two turbines with a minimum rating of 250 kW each, to small clusters of turbines totaling as much as 5 MW. TVP projects are shown in Figure 4. For the most recent projects (six), NREL will furnish a SCADA system to each project site to automatically record meteorological, operational, performance, and other data. This data will then be transmitted to a central location for consistent formatting, verification, and reporting. An important outcome from the TVP program is the information exchange between the participants, and outreach to other interested power providers.



● TVP I Projects

REGION	UTILITY	CAPACITY	TURBINE
Ft. Davis, TX	Central and South West	12 x 550 kW	Zond Z-40A
Searsburg, VT	Green Mt. Power	11 x 550 kW	Zond Z-40FS

★ New TVP III Projects

REGION	UTILITY	CAPACITY	TURBINE
Brownfield, TX	City of Brownfield	6 x 750 kW	NEG-MICON M1800/750
Oklahoma	Central and South West	TBD	TBD
Springview, NE	NPPD/Lincoln Electric	2 x 750 kW	Zond Z-50
Algona, IA	Cedar Falls Utilities	3 x 750 kW	Zond Z-50
Lewis Co., NY	Niagara Mohawk	3 x 100 kW	Northern Power Systems

▲ "Associate" TVP III Projects

REGION	UTILITY	CAPACITY	TURBINE
Big Spring, TX	York/Texas Utilities	4 x 1.65 MW 42 x 660 kW	Vestas V-66 & V-47
Glenmore, WI	Wisconsin PS	2 x 600 kW	Tacke TW 600e
Kotzebue, AK	Kotzebue Electric Association	10 x 66 kW	Atlantic Orient AOC 15/50

Figure 4: EPRI/U.S. DOE technology verification projects.

2.4 Cooperative Research and Testing

The Cooperative Research and Testing program covers a wide variety of industry support, utility analysis, and support and development of certification and standards. The U.S. DOE Wind Energy Program, at the request of U.S. industry, is continuing to play a major role with the International Energy Agency (IEA), Electro-technical Commission (IEC), and major foreign research laboratories to develop international standards and their application for certification test and accreditation programs. Laboratory researchers and industry representatives have served on numerous standards committees. In addition, NREL has been asked by industry to become an accredited test laboratory. With such status, a laboratory can supply test reports to any certification body, European or domestic. NREL is also working with Underwriters Laboratory (UL), the certification agency for the United States, to develop a U.S. certification program. These two efforts – the development of standards and the establishment of a certification capability within the United States – are the major objectives of the Program for this year. Support of standards development will focus on the currently active IEC standards, and the IEEE SCC-21 standard for distributed interconnection.

NREL has already become an accredited testing laboratory for power performance and noise testing with approval from the American Association of Laboratory Accreditors. NREL will continue development and documentation of quality assurance procedures for both testing and full certification capabilities. This will include establishing testing hardware and software, and completing the development and documentation of test procedures for loads, dynamic characterization, power quality, and blade testing. NREL will also conduct tests on turbines being developed in cooperation with the Turbine Research program to assist industry in conforming with international certification requirements. Finally, NREL will continue coordinated testing with international laboratories to establish uniform results from testing procedures. Another important activity for establishing quality assurance between different certification laboratories will be the completion of round robin testing of the AOC 15/50 wind turbine under IEA Annex 16. NREL will continue its duties as Operating Agent for this Annex.

3. SUMMARY

It is not clear if the recent large additions of wind capacity in the United States will continue beyond this summer, when the federal tax credit is set to expire. However, regardless of the status of near-term tax credits, in the long-term, the cost of energy from wind generation must decrease from current levels if the wind industry is to realize its potential in the U.S. market place. RD&D activities sponsored by U.S. DOE, in cooperation with industry partners, provide the capability for achieving such cost reductions and obtaining high levels of reliability. Several research and testing facilities are available for the industry's use at the NWTC. In addition, domestic and worldwide markets for small systems and for hybrid systems present other important markets and unique RD&D needs that the U.S. DOE Program is addressing. By working with industry to build fundamental engineering, scientific understanding, and associated design capabilities, the U.S. DOE Wind Energy Program is helping to equip U.S. industry with the capability to respond to the evolving needs of the market.